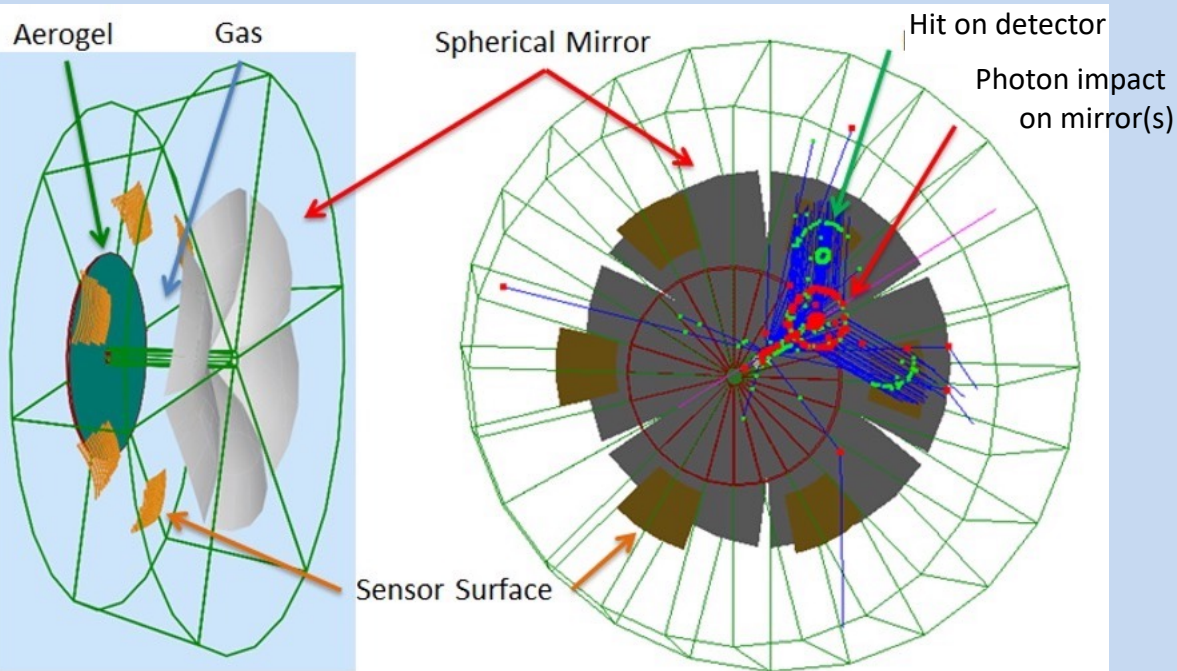


Dual-Radiator RICH

Marco Contalbrigo – INFN Ferrara

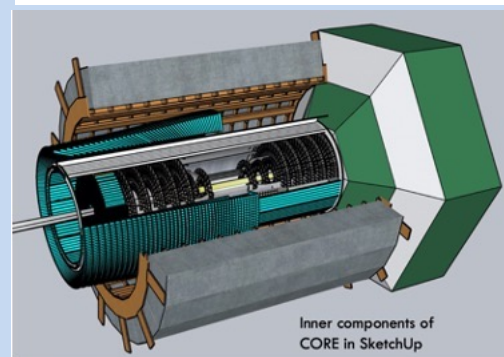
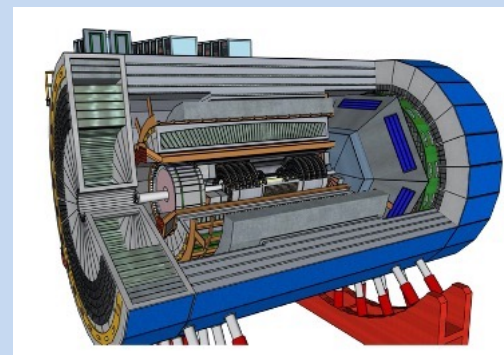
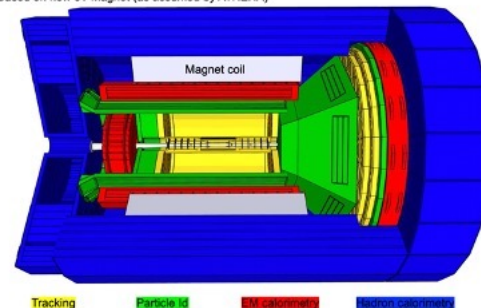
EIC eRD102 Meeting - 7th September 2021

Dual Radiator RICH in EIC Hadron-endcap



- Polar angle: 5-25 deg
- Momentum: 3-60 GeV/c
- Magnet: 3T Solenoid

Based on new 3T Magnet (as assumed by ATHENA)



dRICH: effective solution, part of reference detector

Radiators: Aerogel ($n_{\text{AERO}} \sim 1.02$) + Gas ($n_{\text{C}_2\text{F}_6} \sim 1.0008$)

Detector: 0.5 m²/sector, 3x3 mm² pixel

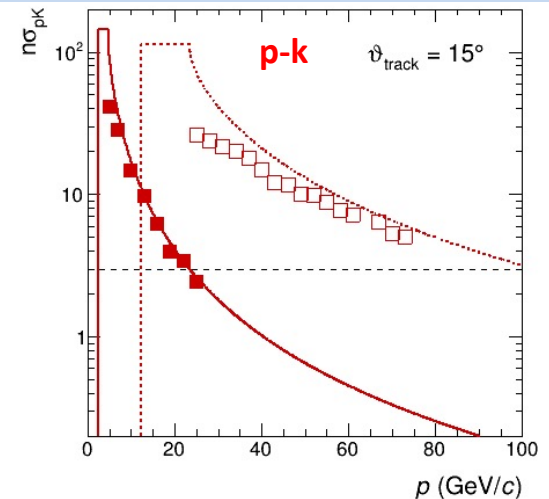
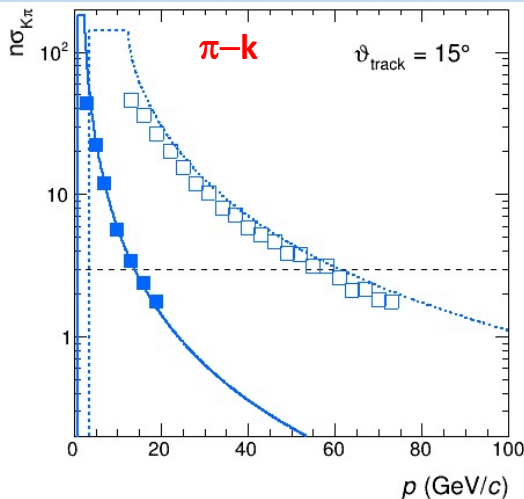
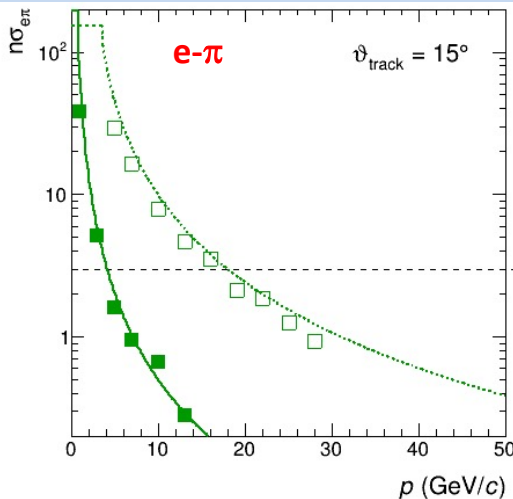
Single-photon detection in $\sim 1\text{T}$ magnetic field

Outside acceptance, reduced constraints

→ best candidate for SiPM option

dRICH Feasibility Study

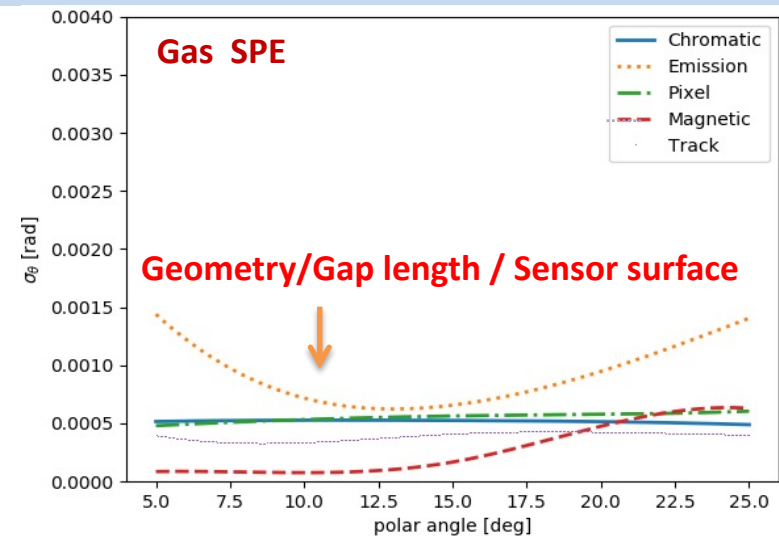
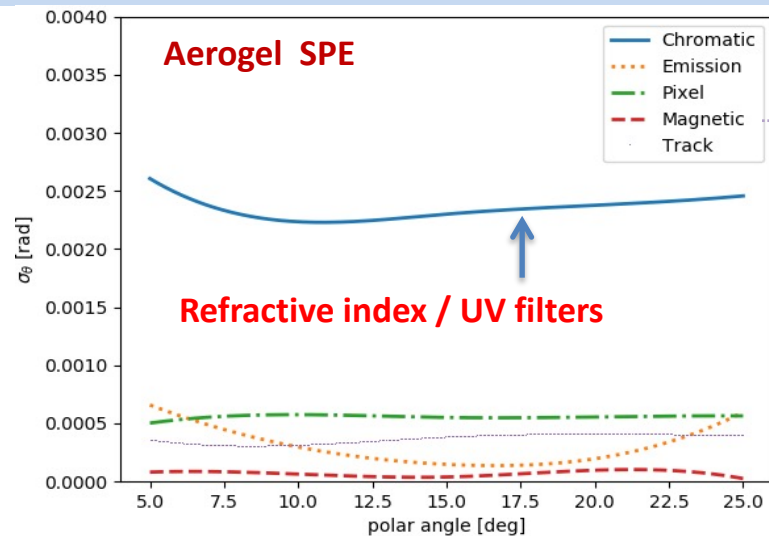
Compact and cost-effective solution for continuous momentum coverage (3-60 GeV/c)
Strong interest in the dRICH electron-pion separation capability



Studied with full Geant4 simulation, with Bayesian optimization and analytic parameterizations

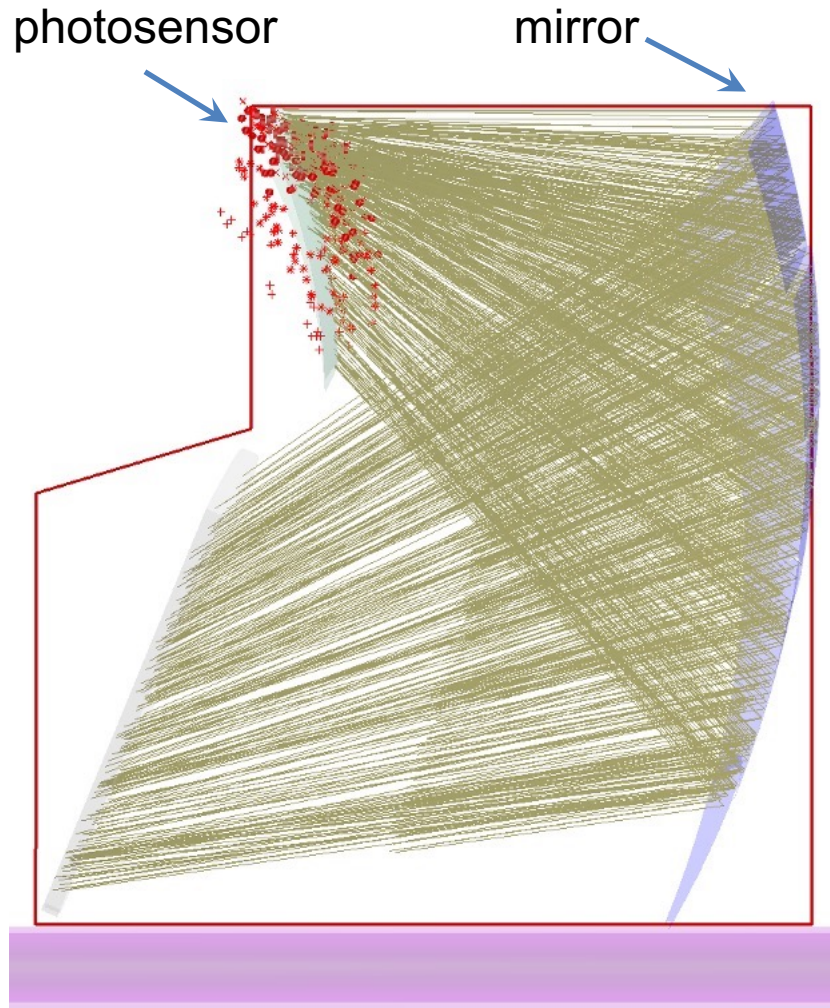
L. Barion et al., JINST 15 (2020) 02, C02040

E. Cisbani et al., JINST 15 (2020) 05, P05009

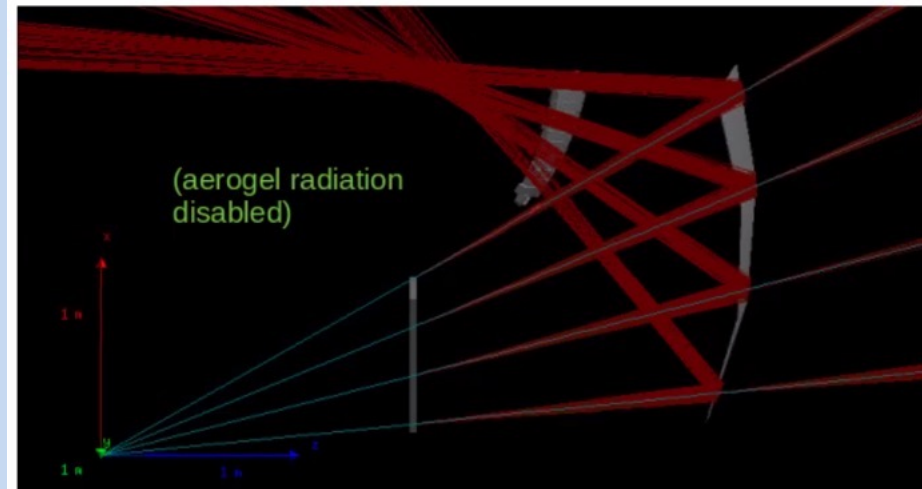
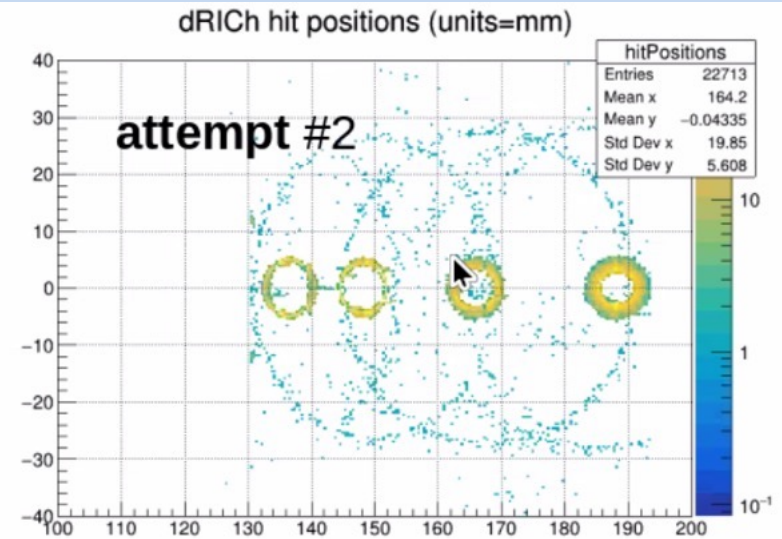


dRICH in ATHENA +....

First attempts to optimize optics in ATHENA with dRICH full simulation framework



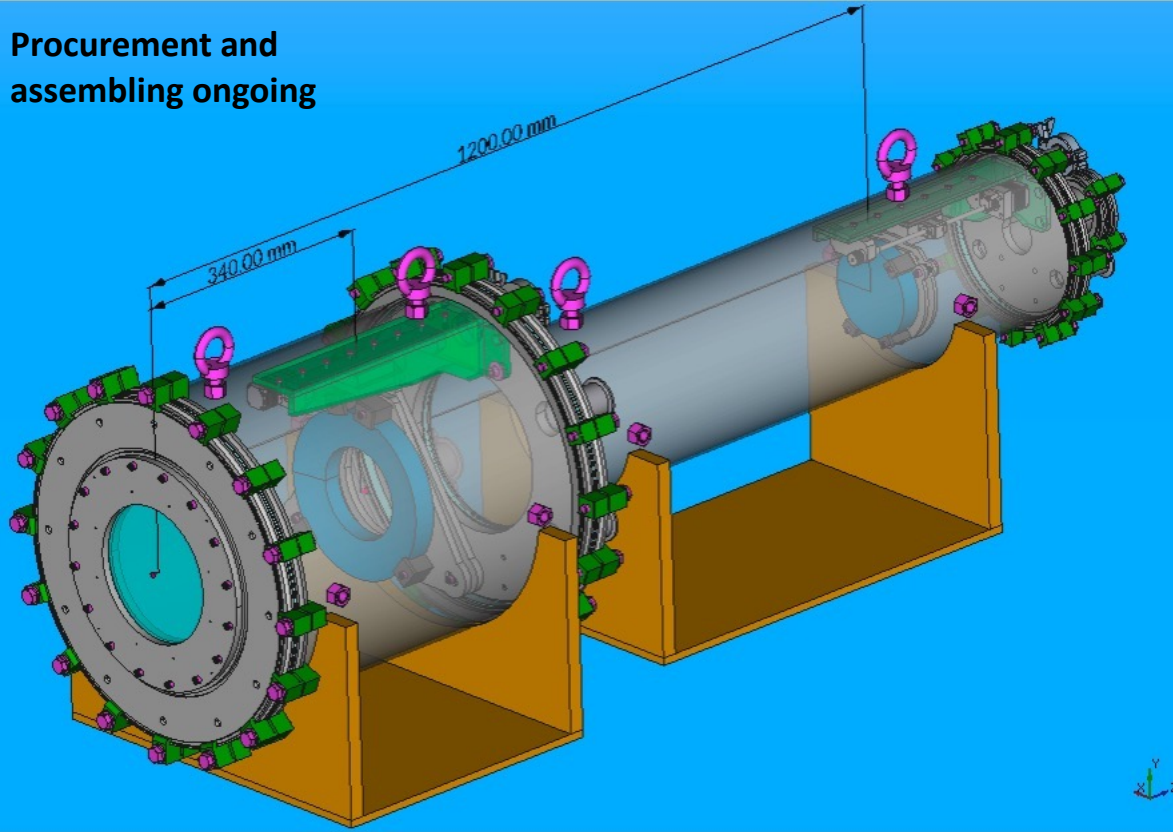
5 x mirror segments



From Christopher Dilks - 1/Sep/2021

dRICH Prototype

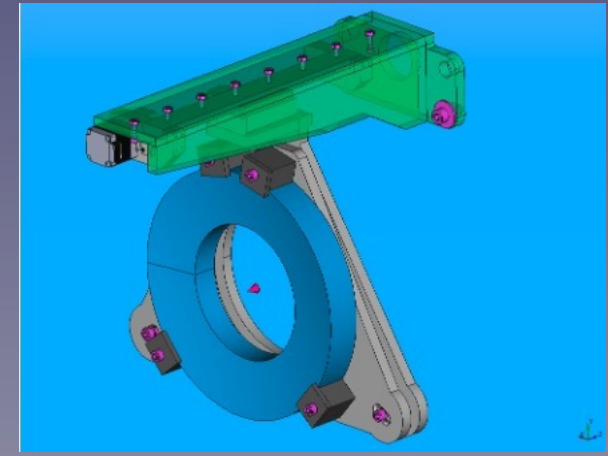
Procurement and
assembling ongoing



Dual radiator imaging

Pressure vessel for gas & n tune

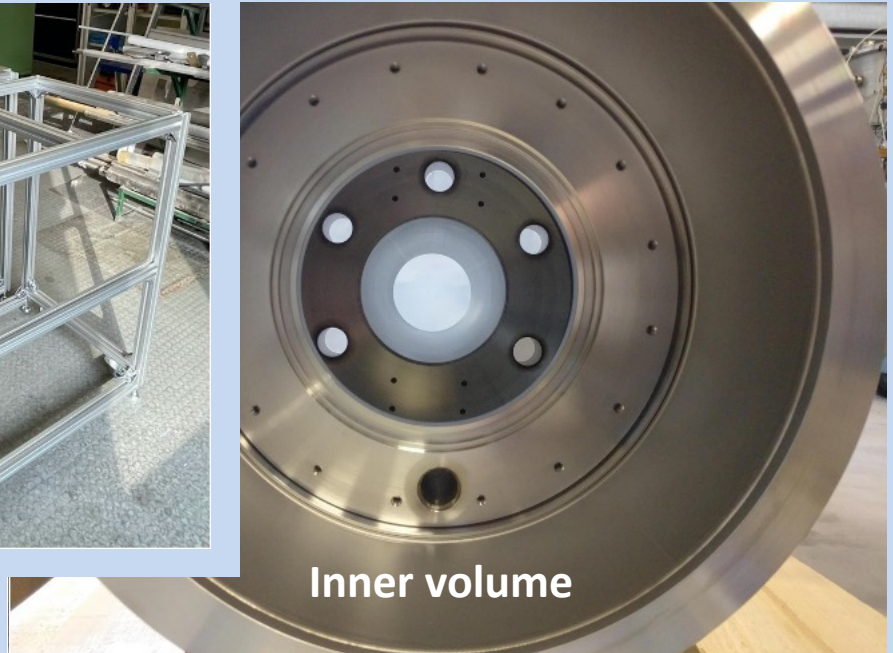
Sensor & readout friendly



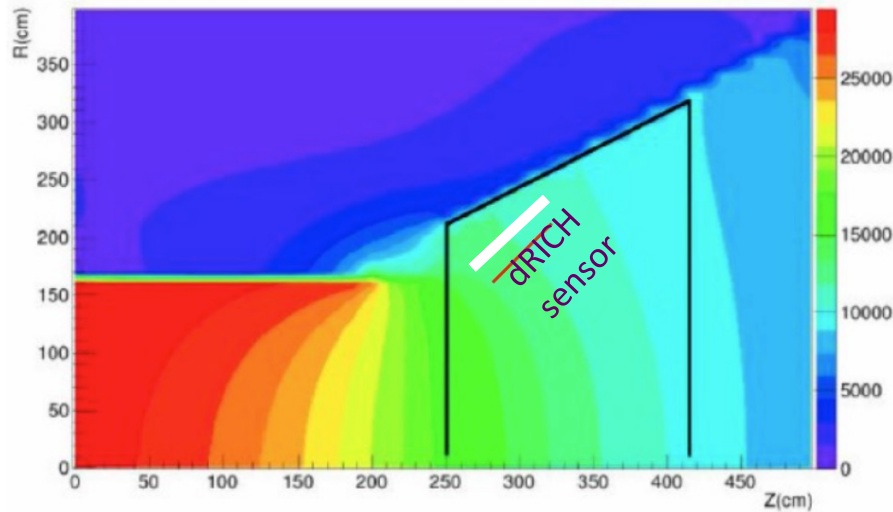
Goals:

- Study dual radiator performance and interplay
- Study specifications and alternatives for optical components
- Test alternate single-photon detection systems
- * First test-beams in September and October '21 at CERN (in synergy with ALICE at PS T10)

dRICH Prototype



EIC Detector Challenge II



High Magnetic Field

~ 1 T order of magnitude, varying orientation

SiPM: PET study up to 7 T [10.1109/NSSMIC.2008.4774097](https://doi.org/10.1109/NSSMIC.2008.4774097)

dRICH sensor location relaxes requirements on neutron dose and material budget

Neutron Fluence

Moderate except for very forward regions

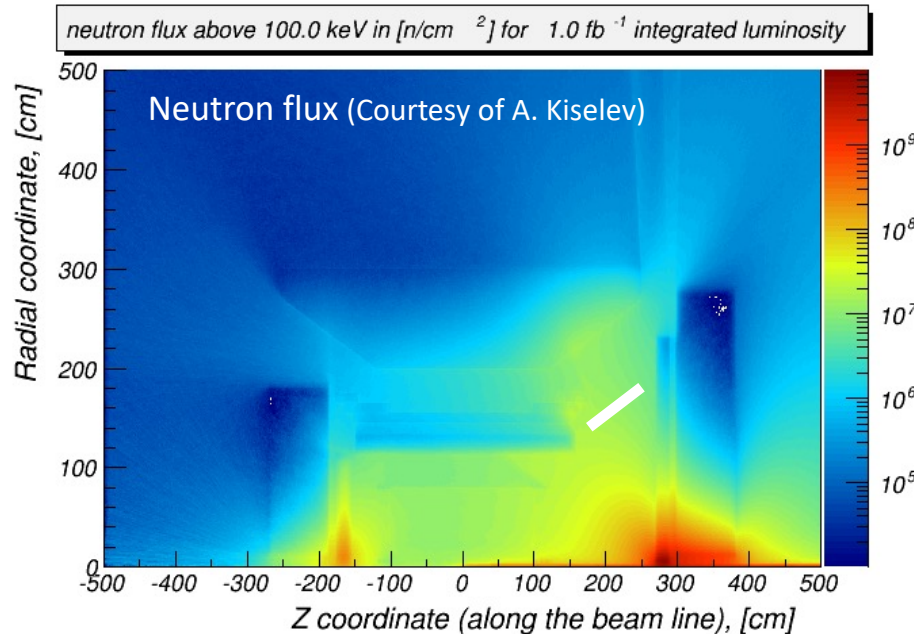
Reference value. ~ $10^{11} n_{eq}/cm^2$

for several years at max lumi (10^{34})

SiPM: radiation mitigation for SPE actively studied

till $10^{11} n_{eq}/cm^2$ and above [10.1016/j.nima.2019.01.013](https://doi.org/10.1016/j.nima.2019.01.013)

[10.1016/j.nima.2018.10.191](https://doi.org/10.1016/j.nima.2018.10.191)



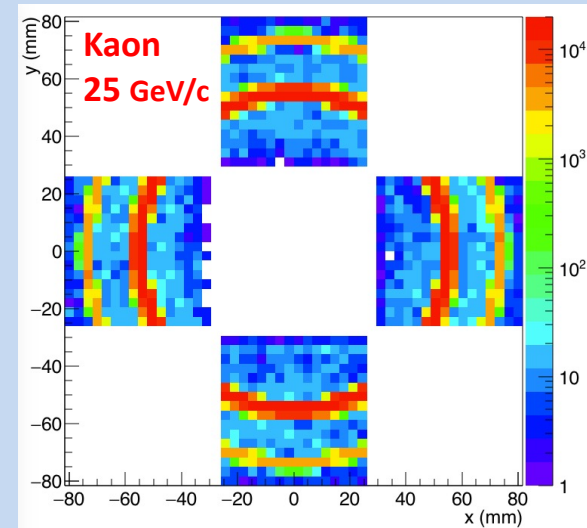
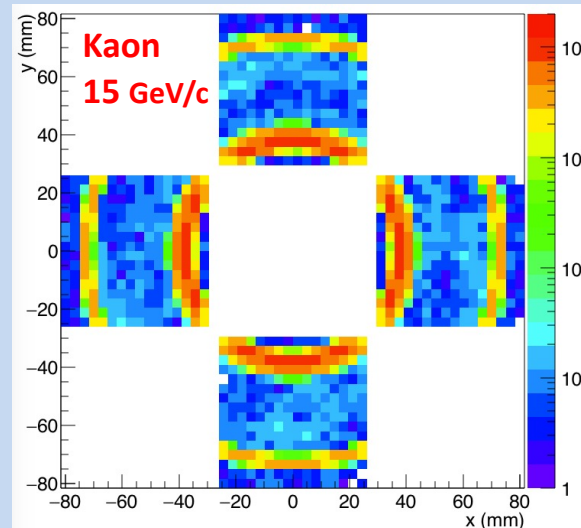
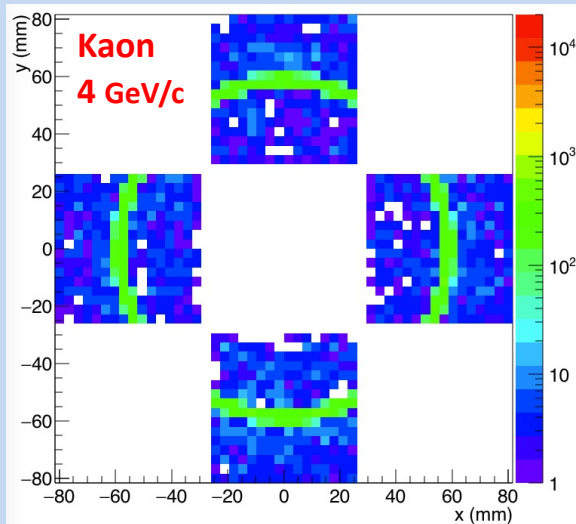
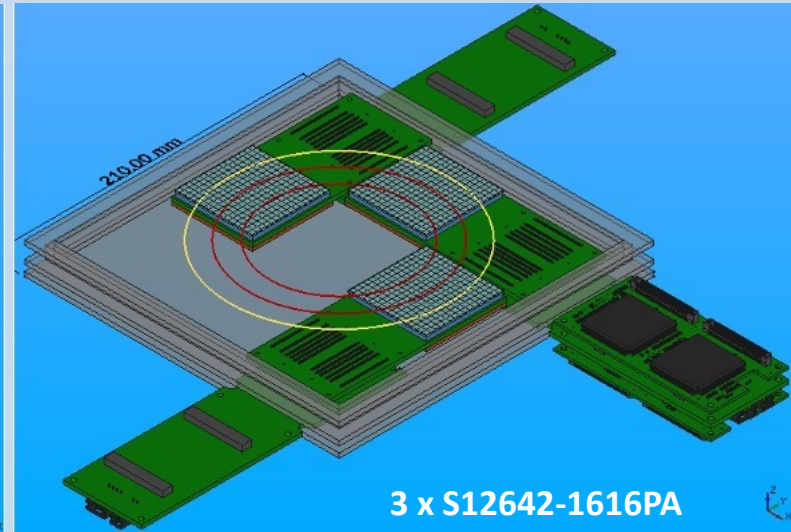
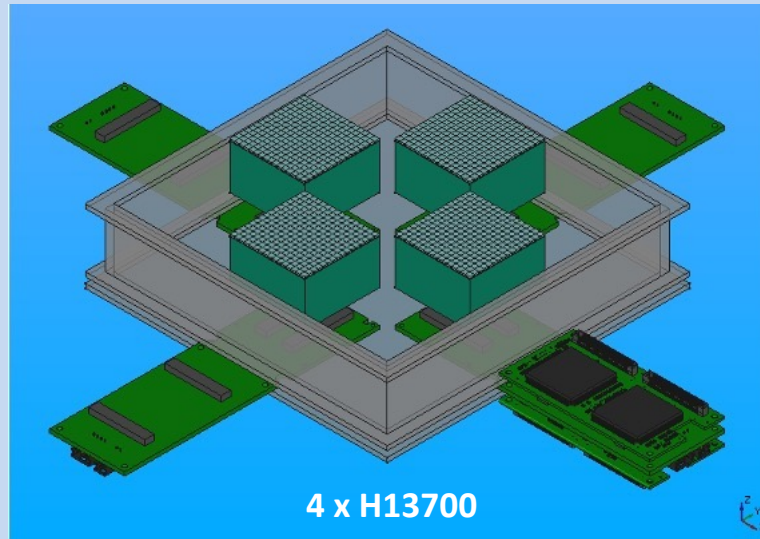
Assumed: independent readout based on SiPM and MAROC electronics

dRICH Prototype Imaging

House the same principles and readout units used for EIC eRD14 test-beams

Compatible with H13700/S12642-1616PA + CLAS12 RICH MAROC front-end

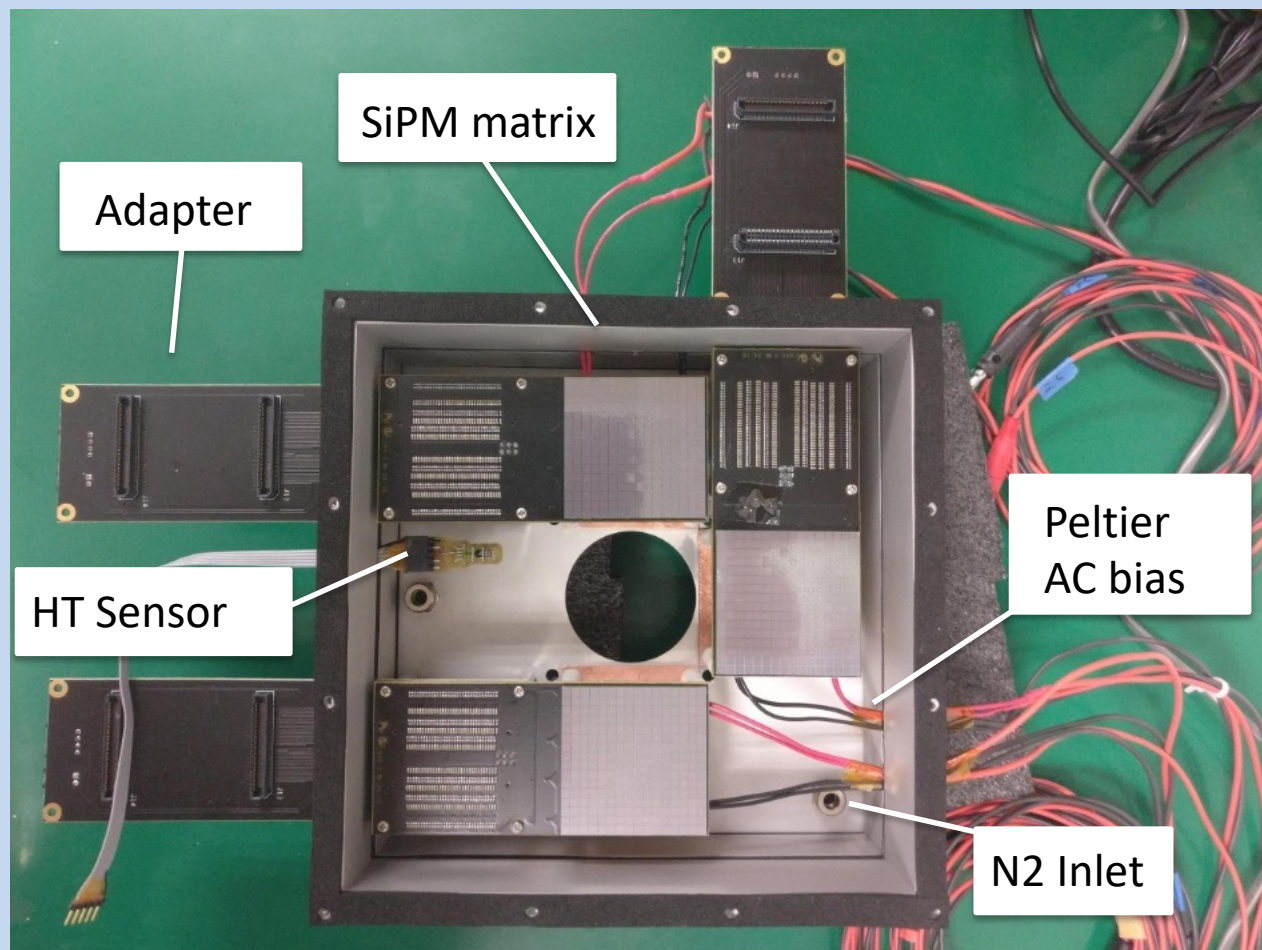
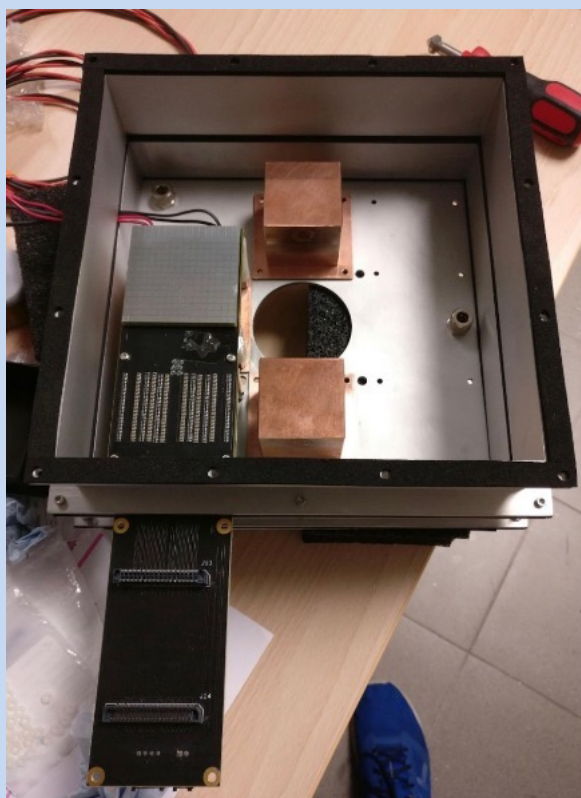
Allows to study the working principles and optical performance of the components



dRICH Detector Box

- 3 versions:
- Detector box for S12642-1616PA matrices of large area ($5 \times 5 \text{ cm}^2$)**
 - Detector box for H13700 multi-anode PMTs (reference detector)
 - Detector box for irradiated SiPM carriers

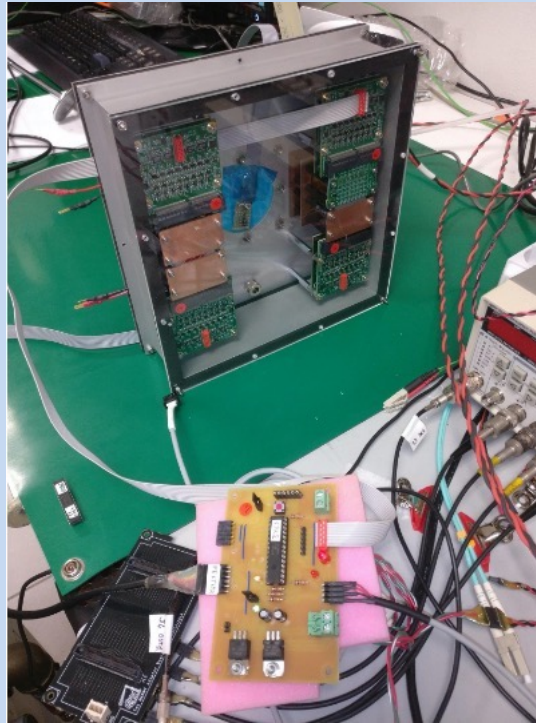
Obsolete SiPM sensors out of market



Ancillary Systems



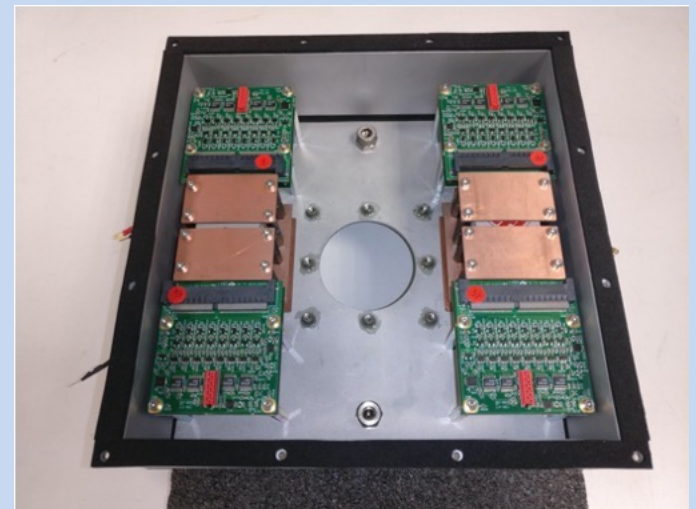
Vacuum test



Cooling system



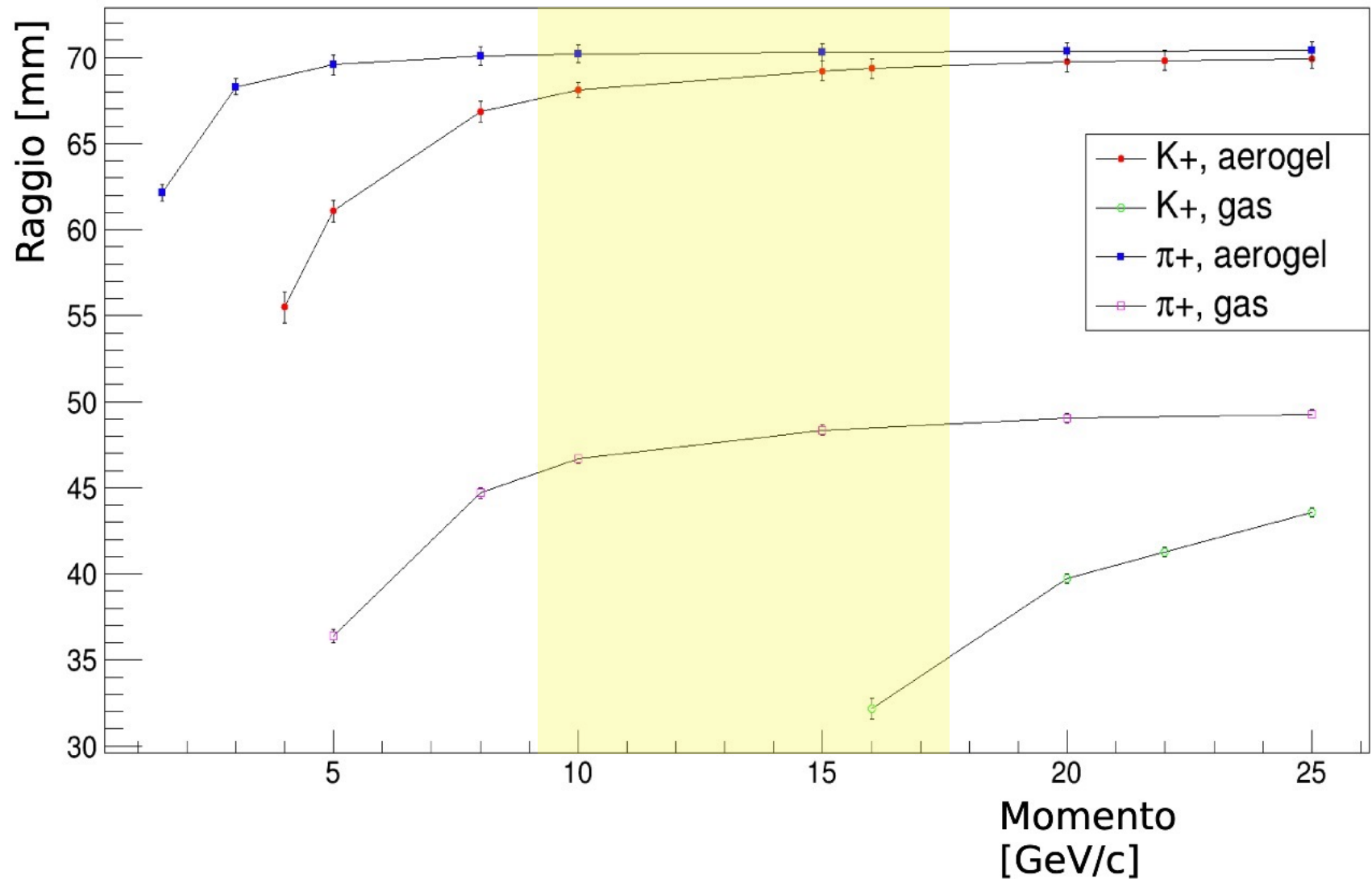
Detector box for
irradiated SiPM



dRICH Prototype Simulation

PS ←

→ SPS



CERN Beam Tests

September '21 @ SPS H6

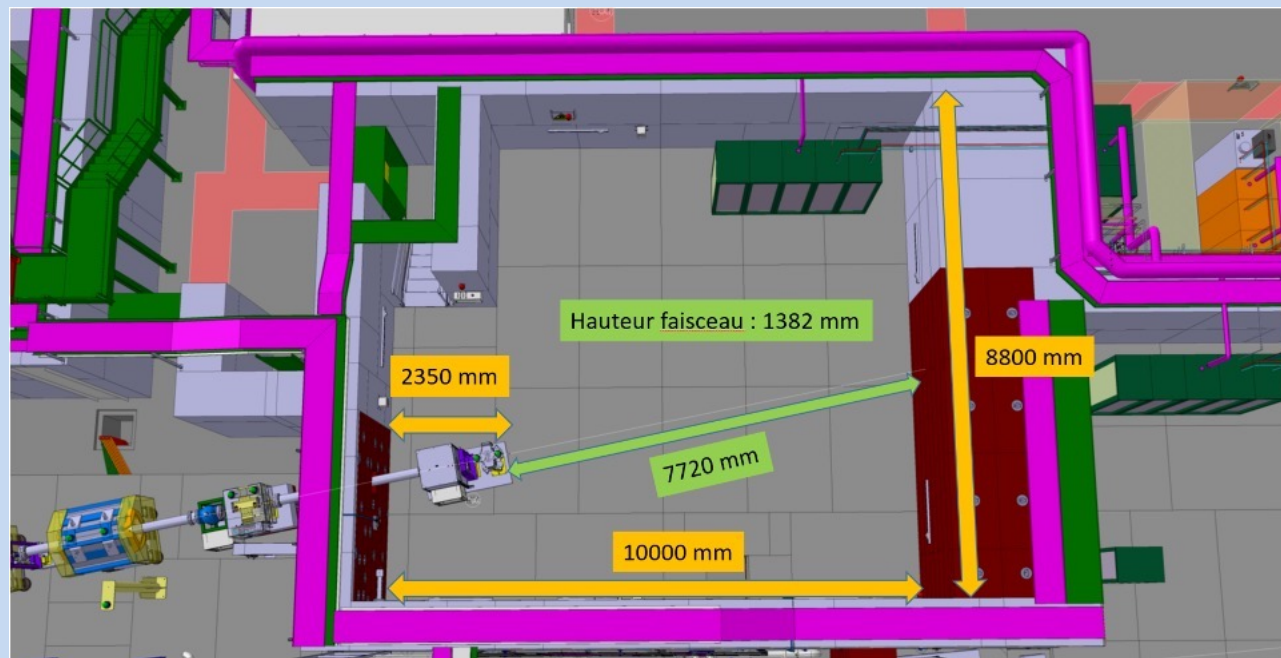
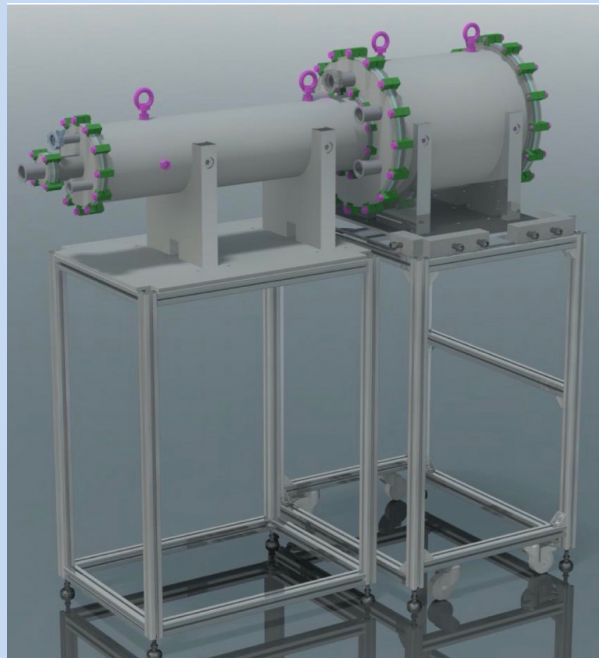
Meson beam up to 15 GeV/c

October '21 @ PS T10

Meson beam from 20 to 60 GeV/c

Goals: Commissioning of dRICH prototype, initial assessment of the dRICH Concept
Asses aerogel (and gas) optical performance
Assess SiPM usage in realistic experimental conditions

Synergy with ALICE for aerogel (Japanese/Russian) and SiPM + ALCOR/ARCADIA readout tests



dRICH Key Hardware Components

Component	Function	Specs/Requirements	Critical Issues / Comments
Mechanics	Support all other components and services Keep in position and aligned	Large volume gas and light tightness; alignment of components	Technically demanding but feasible; no major challenges expected
Optics (Mirrors)	Focus (expecially for gas) and deflect photons out of particle acceptance and reduce sensor surface	sub-mrad precision reflectivity $\geq 90\%$ low material budget	Spherical mirrors technology of CLAS12 suitable (optical fiber and/or glass skin); similar geometry; Development for cost reduction
Aerogel Radiator	Cover Low Mom. Range between TOF and Gas	$\geq 3\sigma$ π -K separation up to Gas region (~ 13 GeV)	Procurement: currently 1 active provider (2 main producers + 1 potential) Long term stability assessment in conjunction with gas
Gas Radiator	Cover High Mom. Range above Aerogel	$\geq 3\sigma$ π -K separation up to ~ 50 GeV and overlap to aerogel	Greenhouse gas: potential procurement issue Search for alternatives
Photon Detector	Single photon spatial detection	Magnetic field tolerant and radiation hardness; \sim few mm spatial resolution	MCP-PMT is likely doable, but expensive. LAPPD may represent an alternative. R&D on SiPM: a promising, quickly improving, worldwide pursued, and cheap technology.
Electronics	Amplify and shape single photon analog signal, convert to digital, transfer to DAQ nodes	Low noise Time res. ~ 0.5 ns μ s signal latency	MAROC3 based readout available for prototyping; final choice will depend on sensor. ASIC development for optimised streaming readout (discrimination vs sampling)

Choice is based on EIC requirements, (current design is aerogel $n=1.02$, gas $n=1.0008$), but needs validation and could be influenced by market availability and mass production quality.

Aerogel

Russia: Budker Institute of Novosibirsk (RAS Siberian branch)

- pros: largest volume (bricks)
highest transparency at large refractive index ($n=1.05$)
experience from AMS, CLAS12, LHCb
- cons: hygroscopic
essentially handmade

Japan: Aerogel Factory Co. (spinoff from Chiba University)

- pros: hydrophobic
with industrial partners
experience from BELLE-II
- cons: to be validated for massive production

USA: ASPEN (collaborating with CUA)

- pros: industrial producer
- cons: to be validated for transparency

Gas

Procurement issue reported (right now: Nippon gases)

C_2F_6 1.00082

CF_4 1.0005

C_4F_{10} 1.0014

Delicate gas handling

greenhouse gases
environmental restrictions

Alternative

Noble gases at high-P

Next Steps: Optical Components

Existing facility to study detailed radiator optical properties and alternatives

Aerogel: Safe handling and characterization
(refractive index, surface planarity, forward scattering)

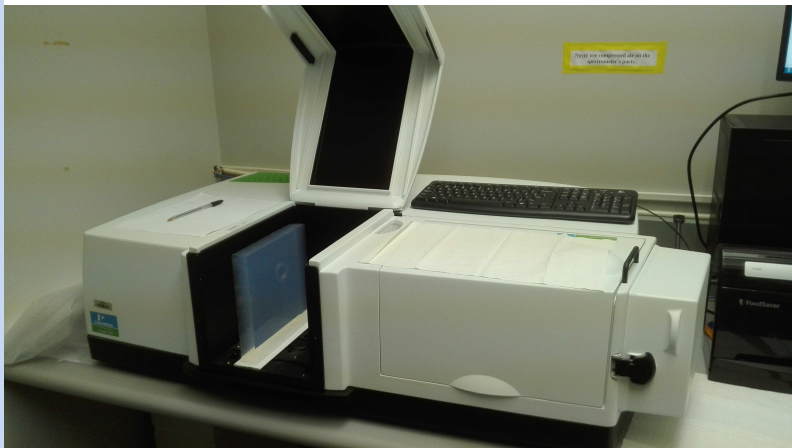
Budker Institute (Russia, CLAS12), Chiba University (Japan, Belle-II), Aspen (USA, R&D)

Gas: Safe handling and purging

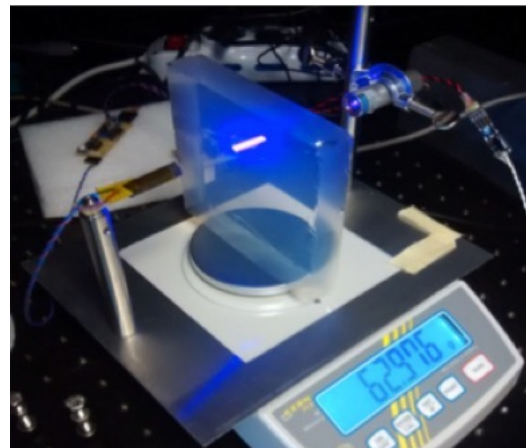
Alternatives to greenhouse gases

Interplay between radiators: UV filters, refractive index optimization

Spectrophotometer



Characterization station



Controlled storage



Next Steps: Optical Components

Existing facility to study detailed mirror optical properties and alternatives

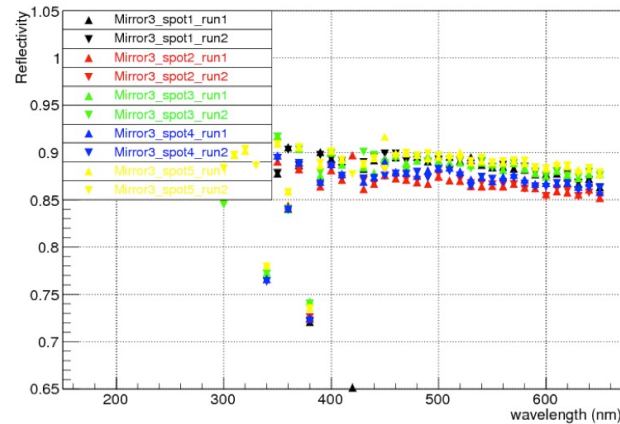
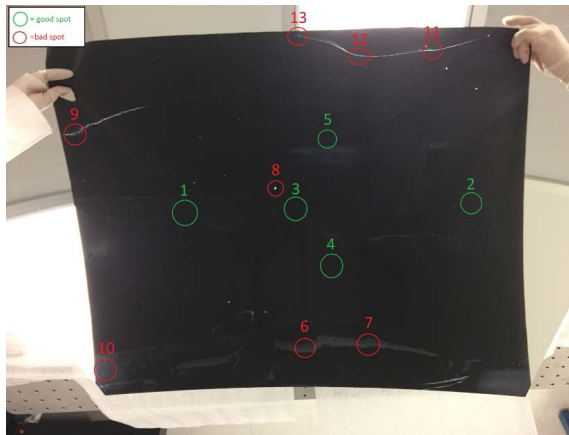
Mirrors: Safe handling and characterization
(surface map, radius of curvature, reflectivity)

Carbon fiber (mature) vs glass skin (cost-effective)

Mechanics: Composite materials from aeronautics technology

Stiff and light, supporting alignment

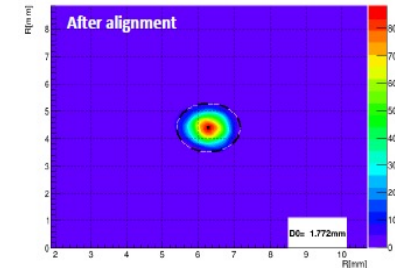
Reflectivity



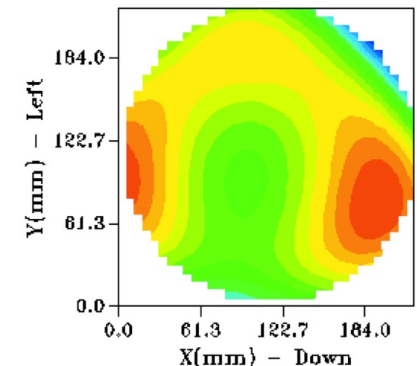
Surface Quality



Pointlike source image



Shack-Hartmann sensor



Goals:

Completion of a test-beam setup able to demonstrate dRICH performance

New test-beam to validate the dual-radiator approach and support the simulations

Study of dRICH basic integration into the EIC detector.

Milestones:

Initial assessment based on the first test beams (3/30/22);

Realization of a suitable detector plane for the dRICH prototype (6/30/22);

Realistic implementation of dRICH into the EIC detector (9/30/22).

dRICH Timeline

Year	Detailed tasks
2021	<ul style="list-style-type: none"> • Development of basic prototype design, simulation and implementation • Optical components: First selection and tests • Basic prototype: Basic tracking, one choice per radiator, glass mirrors, reference readout • Beam Test 1: Proof of principle with reference detectors and readout , ideal beam • Import dRICH simulation into the supported EIC platforms
2022	<ul style="list-style-type: none"> • Analysis of the first test-beam • Refined prototype: refined components and readout, online reconstruction, precise tracking/alignment • Beam Test 2: Performance assessment with reference and custom detectors, hadron tagged beams
2023	<ul style="list-style-type: none"> • R&D on cooling • EIC configuration engineering and integrated PID • Optical components refinement and cost reduction study (e.g. glass-skin mirror)
2024	<ul style="list-style-type: none"> • Component alternatives and optimization • Final prototype: various radiators, custom mirrors, gas system, optimized readout • Beam test 3: Performance assessment with optimized components
2025	<ul style="list-style-type: none"> • Engineering of cooling and services • Beam test 4: Contingency

Assumed funding profile k\$.

	prototype	radiators	mirror	detector	personnel	technical	travel	total
FY22	30	30	0	40	100	10	10	220
FY23	10	20	30	10	100	10	10	190
FY24	0	20	30	0	60	10	10	130

Conclusions

Ongoing effort for the development of a forward RICH detector for particle identification at EIC

Activity plan is organized following the EIC Critical-Decision timeline

Goal:

Cost-effective compact solution for hadron PID in EIC forward region in a wide kinematic range

R&D Activity on innovative aspects and space for synergy with LHC (ALICE) and other EIC eRD

Prototyping and test-beam campaigns to address crucial PID aspects at EIC
(1st joined test-beam on October '21)

Optimized and alternate radiators

Aerogel of medium refractive index and high transparency, noble gas at high pressure

Novel cost-effective single-photon detector solution to be operated in high magnetic field
SiPM post-irradiation characterization and imaging tests (+LAPPDs)

Readout

Alternate ToT architecture (ALCOR chip)

Cooling, support structure

BNL technical support is essential

Custom readout solutions:

ToT readout based on

ALCOR (F/E) + ARCADIA (DAQ)

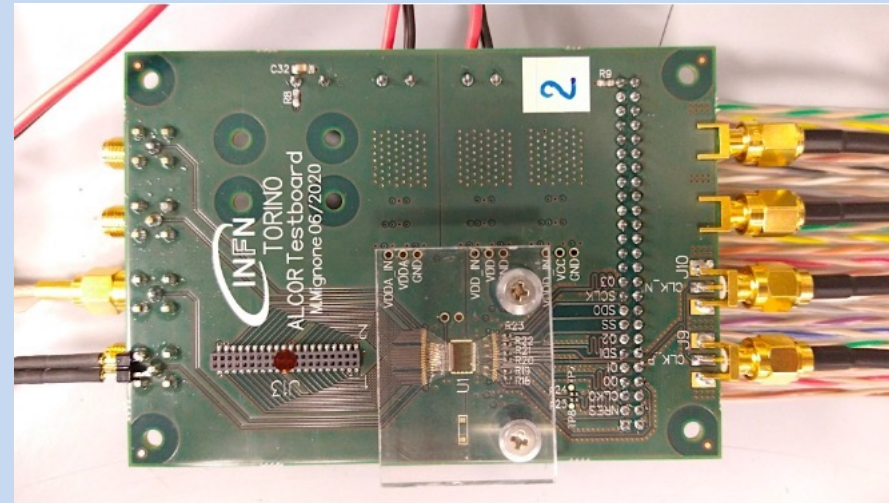
- 500 kHz per channel
- 50 ps time binning

AIDAinnova engineering run: RD_FCC - EIC_NET

Investigate:

- coupling with sensor
- discriminating and TDC logic
- timing performance
- streaming readout

ALCOR test board



SiPM carrier to ALCOR adapter board

